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Research Prospectus for the Simulator Training Research Advanced Testbed for Aviation

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U.S. Army Research Institute

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The cost and complexity of flight simulators has been steadily increasing, but there is little empirical evidence that even high-fidelity simulators are effective training devices. This is especially true in the case of helicopter simulators. Training system developers opt for the highest fidelity simulators available. However, in a cost-constrained environment, military training developers must weigh fidelity and training effectiveness against cost. In the absence of research data, it is difficult to determine when high-fidelity simulation is needed and when it is not. The Simulator Training Research Advanced Testbed for Aviation (STRATA) is a research simulator designed to address issues pertaining to simulator training effectiveness and the training system complexity needed to accomplish specific training objectives. It is modular and can be reconfigured to represent different training devices with different visual, motion, cockpit, and aeromodel subsystems. This report will serve as a guidance document and program planning aid for developing more specific research plans for the simulator.

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Human Performance Effectiveness and Simulation

FOREWORD

The U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) at Fort Rucker, Alabama, is committed to enhancing aviation training. A cornerstone of this commitment is the Simulator Training Research Advanced Testbed for Aviation (STRATA). This research prospectus for STRATA was initiated in ARIARDA in March 1992 to investigate STRATA fidelity requirements for rotary-wing aviation training.

Flight simulators have become increasingly complex and costly. Many current simulators are high-fidelity devices--they attempt to reproduce, as closely as possible, the experience of flying the aircraft they represent. Evidence for their training effectiveness, especially in the case of helicopter simulators, is limited.

Typically, simulation training research has been narrow in scope, limited to a particular training system in its own unique setting, and had to take place on a noninterference basis. These limitations frustrated simulation researchers and prompted the development of STRATA. STRATA is not a dedicated training device; it is a research testbed for developing training concepts. It is modular and can be reconfigured to represent alternative training devices with different visual displays, motion systems, cockpits, and aeromodels, something that cannot be done with most operational training simulators. This should provide valuable guidance for the development of modular, portable simulation training devices and a total Army aviation training system that will maximize training effectiveness and efficiency.

This prospectus was jointly developed by the Army aviation community and ARIARDA. The goal was not to delineate precise hypotheses nor methods for future research, but to impart structure to the STRATA research program. The prospectus will likely be modified and upgraded periodically.

This material was briefed to the U.S. Army Aviation Center at Fort Rucker, Alabama, in August 1992; to the Army Simulation Training and Instrumentation Command in November 1992; and to the Naval Air Systems Command in December 1992. The outcome of these briefings was an increased interest in STRATA as a system for answering critical training and simulator development questions that cannot be answered adequately with operational training systems.

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RESEARCH PROSPECTUS FOR THE SIMULATOR TRAINING RESEARCH ADVANCED TESTBED FOR AVIATION

EXECUTIVE SUMMARY

The U.S. Army Research Institute (ARI) recently acquired the Simulator Training Research Advanced Testbed for Aviation (STRATA). The primary simulator mission is training effectiveness research for a variety of aviation training device configurations. The focus will be on pilot skill acquisition and maintenance and performance enhancement. Most conventional simulators are designed to support specific training objectives. It is impractical to modify them to address questions concerning alternative simulator designs or to obtain objective data from them relating to these questions. STRATA has been purposely designed to allow for changes in hardware configuration. It is a true testbed simulator that can be rapidly and extensively reconfigured to meet a variety of research objectives.

Requirement:

Flight simulators have been increasing in both cost and complexity. Their use for purposes of research has been limited and has often been narrowly focused. More often than not, they are integrated into training systems with minimal prior research on their effectiveness. Still, many simulators are high fidelity devices--they attempt to replicate as closely as possible most or all of the characteristics of the aircraft. Even so, there is a paucity of empirical data to provide guidance as to what simulator systems (e.g., visual display system, motion system, cockpit) must closely resemble those of the aircraft to accomplish a given training objective.

Procedure:

This prospectus synthesizes the projected areas of research into a coherent, programmatic document. It can serve as a planning vehicle for the development of a specific research program for STRATA. The prospectus seeks to identify the major issues raised by previous simulation research and demonstrate how STRATA, with its unique properties, can serve as a research tool.

Findings:

Reviews of the simulation research literature indicated a large number of unresolved issues that STRATA was designed to address. This prospectus suggests new directions of research in such areas as psychophysics, transfer of training, visual scene content, motion cuing, and tactical issues such as helicopter air-to-air combat.

Utilization of Findings:

This prospectus serves as a research guidance document. More detailed research plans for STRATA will be prepared for each of the above issues. For example, extensive programmatic research on perception, using the prospectus as a reference point, was developed. Further research program planning grew out of the STRATA research prospectus.

RESEARCH PROSPECTUS FOR THE SIMULATOR TRAINING RESEARCH ADVANCED TESTBED FOR AVIATION

CONTENTS

LIST OF FIGURES

Research Prospectus for the Simulator Training Research Advanced Testbed for Aviation

Introduction

Statement of the Problem

Cost and complexity of simulators. Flight simulators are becoming increasingly complex and costly. For many training objectives, these costs are now prohibitive. This was pointed out by the United States Army Audit Agency (AAA) reports of March 1982 and August 1984 on synthetic flight training systems. The AAA reports went on to state that the benefits of these costly, highly complex devices for unit training have not been conclusively demonstrated. The House Armed Services Committee on Research, Development, Test, and Evaluation (HASC/RDT&E FY 86 Mark, pp. 130-131, May 1985) called for the development of training devices that are demonstrably cost and training effective. These would have to be simpler than current simulators, adaptable to different training milieux, and inexpensive enough for use by Guard and Reserve units. The Congressional commitment to minimum complexity for maximum effectiveness in simulator design and use is even more crucial in the fiscally constrained decade of the 1990s.

Evidence of training effectiveness. According to a recent review (Hays, Jacobs, Prince and Salas, in preparation), much of the research on aviation simulation has been narrowly focused on simulators in specific training situations. The research has also been restricted primarily to individual as opposed to crew-level skills. The authors, in their review of current flight simulation research, state that this limited perspective is dictated by the necessity to employ the simulator as a training device before it has been shown to be effective. Hence, investigators are concerned with showing that training time in the simulator transfers positively to performance in the aircraft, for their particular device at their location. Because the research is usually conducted using unit aviators on a non-interference basis, experimental control is often compromised. Salient issues, such as the minimum amount of simulator complexity required for training effectiveness, are seldom addressed. Hays et al. imply that simulator developers and users have assumed that the more the device resembles the aircraft, the more effective it should be. This philosophy persists in spite of evidence that in order to be training-effective, simulators do not necessarily have to resemble closely an actual operational aircraft (Caro, Corey, Spears and Blaiwes, 1984; Lintern, 1991; Lintern, Roscoe and Sivier, 1990; and Wightman and Sistrunk, 1987).

One important finding of the Hays et al. meta analysis was the paucity of definitive research on the effectiveness of helicopter simulators. They were only able to locate seven helicopter experiments, and not surprisingly, found only a negligible difference between simulator plus aircraft training vs. aircraft training alone. Consequently, there is very little in the way of generalizable research supporting the contention that helicopter simulators are effective training devices.

Training vs. research simulators. With few exceptions (Collyer and Chambers, 1978; and Larson and Terry, 1975), simulators have been built and sold for training, not for research. Their effectiveness as training devices has been assumed, but, in most cases, not demonstrated. The use of flight simulators for research has been limited. More often than not, simulators are integrated into training systems with minimal prior research. The typical Army Operational Test II (OT II) acceptance methodology for a new simulator consists of assigning a senior aviator with many hours in the aircraft the task of evaluating its performance. The pilot flies the simulator, comparing its performance to that of the aircraft by making subjective judgments about its handling qualities. The software aeromodel is then revised to correspond to the pilot's expert judgments. A set of engineering performance tests of two Army simulators by Hogue, Jex, and Magdaleno (1982) using more precise, objective measures suggested that the Army acceptance methodology did not work well. Among their findings was the discovery that, for a UH-60 simulator with a six degree of freedom motion base, two degrees of freedom had been eliminated as a result of OT II. The simulator had only four of the six degrees of freedom.

Overview of the Simulator Training Research Advanced Testbed for Aviation (STRATA)

STRATA as a dedicated research platform. The U.S. Army Research Institute (ARI) recently acquired a unique simulation system. It is ideally suited for investigating alternative simulator configurations and their effects on training. Since most operational simulators are designed to support specific training requirements, it is impractical to modify them in order to address questions concerning simulator design, or even to obtain objective data on performance. STRATA, by contrast, has been purposely designed to allow for such modifications as well as for the routine collection of objective human performance data. STRATA provides a high level of versatility for conducting research.

STRATA was developed by ARI under a U.S.-Canada Defense Development Share Program, approved by the Secretary of Defense. Initial delivery to Fort Rucker, Alabama took place in May 1992. Locating STRATA at Fort Rucker is critical to the success of this research program. Unique resources for helicopter simulation research can be found there. Among these resources are numerous Army students and instructor pilots, Army aviation tactics experts, Training and Doctrine Command (TRADOC) systems managers, and the U.S. Army Aviation Center.

The lack of modularity among most current simulators makes it difficult, costly and time-consuming to change even minor aspects of configuration or function. This is a deterrent to the conduct of research on the effectiveness of different subsystems that comprise a simulator. By contrast, STRATA is a true simulator testbed that can be quickly and extensively reconfigured. Among its many innovative features are (a) completely modular software, hardware, and data recording, (b) an interactive tactical environment tailored to the high-intensity Army aviation battlefield, (c) head and eye-tracking to drive high detail computer-generated imagery and to record gaze-point, and (d) programming of multiple scenarios to support research in a multi-player tactical context.

A brief description of STRATA. STRATA and its components are described in greater detail in Kurts and Gainer (1991). A brief description of the hardware would be appropriate at this point. STRATA consists of (a) a pilot station consisting of the cockpit shell of an AH-64 equipped with a G-seat to provide motion cues and mounted on wheels so that it can be mated with various visual display systems; (b) a copilot/gunner station also equipped with a G-seat built along the same guidelines as the pilot station; (c) the fiber-optic helmet-mounted display (FOHMD) which is the primary visual display system, providing a virtually unlimited field-of-view (FOV) along with high contrast and brightness and which is equipped with an eye-tracker; (d) the alternate display, which consists of three rear-projection screens with a FOV of 120° horizontally and 60° vertically; (e) the experimenter-operator station (EOS), a control station from which researchers can control and monitor the experiment; (f) the interactive tactical environment management system (ITEMS) which can support up to 180 players in the simulated world, the database management system (DBMS) and data recording/analysis (DRA) workstation, which support, among other things, tactical scenario generation and performance measurement; (g) the blue/red team (BRT) station, which allows the experimenter to control any player in the experimental scenario from the EOS; (h) the host computer; (i) the visual system, which comprises its own host computer and an image generator, and (j) the visual database modeling workstation, which can be used to modify existing visual databases and create new ones.

Research objectives: STRATA research objectives are closely related to the technology of simulator design and the application of this technology to training strategies. The immediate objective of the research program is to employ this simulator-based research tool to address four major issues: (a) the minimal level of fidelity required to meet training objectives, (b) the most effective (in terms of outcome and cost) use of flight simulation technology to attain and sustain combat readiness, (c) the most effective ways of defining the use of new operational equipment, tactics, techniques, and procedures in a realistic threat environment, and (d) incorporating lessons learned through STRATA into the development of modular, portable simulation systems.

<u>Network capabilities</u>. Within the Army, the prospect exists for networking STRATA to the Army Aeroflightdynamics Directorate's Crewstation Research and Development Facility. It could also be employed as a high fidelity node for the Battlefield Distributed Simulation-Development program. Such an arrangement could provide a unique opportunity for these simulator research resources to conduct cooperative research on emerging issues in collective combined arms environments. A related concept is the Defense Simulation Internet (DSI) network. DSI allows simulators which are located at considerable distances from one another to interact as nodes on a network. Presently, memoranda of agreement exist between ARI, the U.S. Air Force's Armstrong Laboratory, and the U.S. Army Simulation Training and Instrumentation Command (STRICOM) for making STRATA a player in this network. In the future, it is conceivable that STRATA, at Fort Rucker, could participate in joint mission rehearsal exercises with MH-60 and MH-53 simulators at Fort Campbell and Kirtland Air Force Base.

<u>STRATA as a virtual reality research testbed</u>. Baum (1992) defines virtual reality as a simulation in which the individual is immersed in a realistic, computer-generated world. It may well become the training medium of choice in the next century. The student pilot, instead of observing a two-dimensional scene in front of the simulator cockpit, will find himself surrounded by a three-dimensional synthetic world.

STRATA, with its FOHMD, is capable of addressing issues concerning virtual reality, via a three-dimensional, high-resolution eyepiece inset. This technology will involve the creation of a realistic battlefield environment with the necessary out-the-window information displayed on the FOHMD. Given the small space requirements for this device, the FOHMD may be employed together with an image generator in a portable system which could be carried to the field and used as a full-mission field trainer. The virtual reality concept has the potential for adding a dimension of realism to mission planning and rehearsal for units on the battlefield. The boundary between planning and rehearsing the mission would become blurred. Empirical questions concerning the relative advantages and disadvantages of virtual reality can also be addressed by STRATA. In addition to the FOHMD, STRATA also has a two-dimensional, rear projection visual display system. Comparisons between these two visual displays should provide objective data on those training situations in which the three-dimensional imagery would enhance training performance, and those in which it would not.

Baum (1992) discusses some of the advantages of future virtual training devices (VTDs). Many of these advantages and trade-offs are quite germane to STRATA's mission as a research testbed for training devices. He foresees VTD's as being more portable than current generation simulation and training devices, more easily reconfigured to adapt to different training environments, and more cost-effective because of less dependency on complex hardware. Although optimistic about the future of VTD's, especially in networked simulator settings, Baum still cautions that there are challenges that must be met before highly training effective devices are developed. One key issue that must be addressed is the fidelity required for the VTD environment. For some training environments, object density may be more important than level of detail, whereas for others (e.g., identifying targets) a high level of detail would be essential. Similarly, it may be that different levels of fidelity of the virtual world may suffice, depending upon the level of pilot experience.

Selective Fidelity

Difficulties defining fidelity. Unfortunately, there is no single, universally-accepted definition of simulation fidelity. Borrowing a two-part typology from Allen, Hayes and Buffardi (1986) we can conceptualize fidelity as the degree to which the configuration of the simulator (e.g., cockpit, controls, switches, and the visual scene) correspond closely to the actual aircraft (physical fidelity) and the degree to which the simulator successfully mimics performance of the aircraft (functional fidelity). The higber a simulator is on both fidelity dimensions, the more closely it should create the illusion of flying the actual aircraft.

The question that remains to be answered is whether or not high physical and functional fidelity are required for a simulator to be training effective. It is possible that for some training objectives, a device which is only an analog of the aircraft, in that it trains and reinforces skills similar to those required to operate it, would be just as effective.

Selective fidelity in the context of training device development. One of the most critical notions influencing the development of modular training devices is selective fidelity (Boyle and Edwards, 1992). This is an important part of the rationale for STRATA, which is intended as a front-end analysis tool for examining the impact of selective fidelity and cost tradeoffs on training system effectiveness. The reasoning behind the concept of selective fidelity is that high fidelity be reserved only for those components of training devices where it has been demonstrated to be essential to specific training objectives. In this way, simulators with less complexity than a full-mission simulator (FMS) can nevertheless be just as effective for some or most critical tasks.

Figure 1 shows the modular components that comprise STRATA, and other modular simulators. It illustrates how the components can be reconfigured to represent different training devices. The cockpit shell consists of the actual cockpit of an AH-64 helicopter, complete with all instruments. The aeromodel is the aerodynamic model using a blade element approach which accurately simulates the flight characteristics of the AH-64. The fidelity of all of the components shown in the columns of the figure can be varied in order to study the relative cost/training effectiveness of different combinations of fidelity.

MODULARITY AND THE DESIGN OF TRAINING DEVICES

COCKPIT SHELL	AEROMODEL	VISUAL	FLT INSTRUMENTS	MOTION	WEAPONS	DEVICE
✓	✓	✓	✓	✓	✓	COMBAT MISSION SIMULATOR
✓	✓	✓	✓	✓		FLIGHT SIMULATOR
✓	✓	✓	✓			PRIMARY FLIGHT TRAINER
✓	✓	✓				PART-TASK TRAINER
✓	✓		✓			INSTRUMENT TRAINER
✓			✓			COCKPIT PROCEDURES TRAINER
	✓		✓			INSTRUMENT FAMILIARIZATION TRAINER

Figure 1. STRATA modularity and its application to the design of training devices.

STRATA can be used to explore the cost-benefits tradeoffs (in terms of training effectiveness) of using a simpler cockpit shell with only those instruments essential for the training task at hand (e.g., hovering). A generic aeromodel which has comparatively less fidelity to the AH-64 could also be used. Likewise, the resolution of the visual system can be varied, and motion cues can or cannot be used. This example is intended to illustrate the unique mission of STRATA as a selective fidelity research tool.

Figure 2 shows in greater detail than Figure 1 the STRATA components that comprise the aeromodel. The research question concerns just how complex an aeromodel we would need for the design of a helicopter simulator or part-task trainer, given a specific set of training objectives and budgetary constraints. To determine what specific aerodynamic modeling would result in the best training outcomes under the cost ceilings, we could vary motion cuing by either using or not using the G-seat, could compare software helicopter and blade element models varying in complexity, and vary the amount of terrain visual cues available by experimenting with different levels of visual scene contrast and detail.

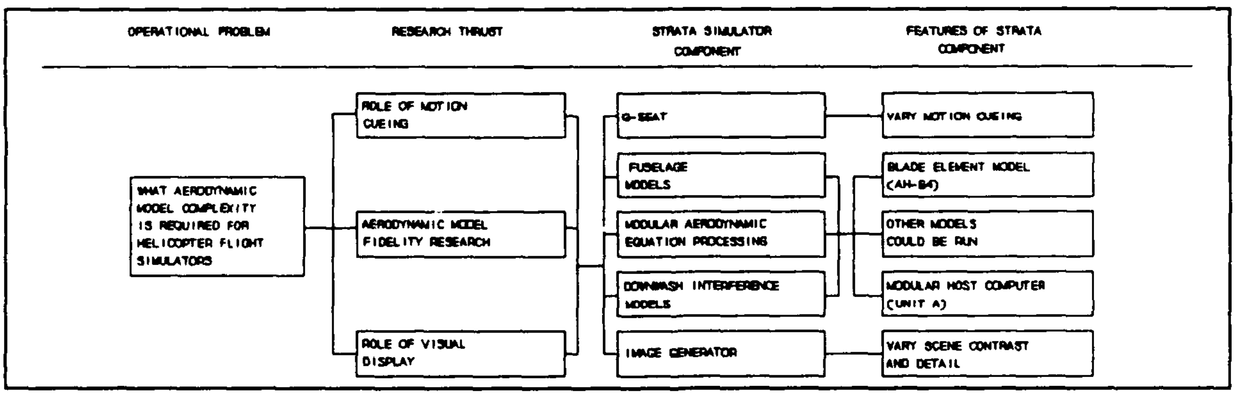

Figure 2. Application of STRATA modularity to a simulator design issue.

<u>The role of STRATA in the development of selective-fidelity systems</u>. STRATA is intended to serve as a research platform for various training devices. Research will be directed toward providing guidance to materiel and training developers. Examples of anticipated products (e.g. portable, modular part-task trainers) serve to guide the designs of cost-efficient visual systems, and recommendations for development of systemic training programs, of which the simulator or trainer is an integral part.

Figure 3 is a graphical portrayal of the "Stairway to Readiness" concept of Army aviation training. The stairway progresses from those forms of instruction normally not requiring training devices, to those which require the use of aircraft. Intermediate steps represent training devices varying in complexity, from simple personal computer-based interactive devices to part-task training devices, and finally to full-mission simulators, some of which are networked with one another. The area where the need is today most critical consists of the intermediate steps, encompassing part-task trainers to portable simulation devices. It is the intermediate levels where STRATA's potential contribution is most promising.

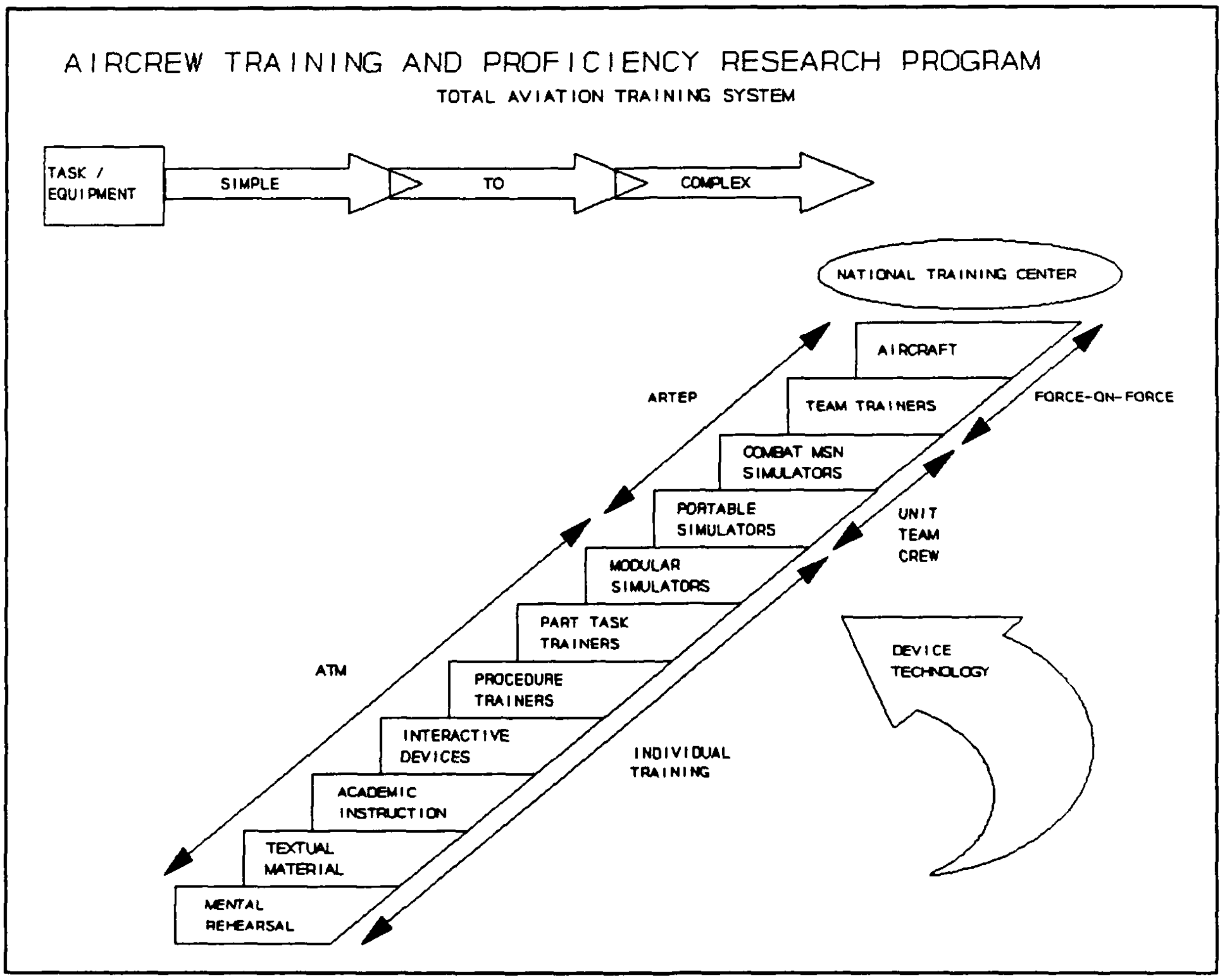

Figure 3. The role of modular, portable training devices in the "Stairway to Readiness."

The imposed cost constraints have already had an impact on the design philosophy of military aviation training systems. A few examples of current design efforts deserve recognition.

Low-Cost selective-fidelity training systems. Several good examples of modular training devices are currently under development. These will be discussed briefly in order to give the reader a feel for the kind of training devices that could be developed from STRATA. The unique thing about STRATA is that its use can determine the training effectiveness of these modular, portable devices before they are designed and built. In other words, STRATA allows for the proactive development of training devices. The users of the devices will know the level of effectiveness before they are issued to operational units. The development of the devices discussed below was driven primarily by cost. Their developers were able to demonstrate that they were training effective after they were built. With STRATA, devices can be configured, different component combinations tested for effectiveness, and the final, most effective combination of components can provide the basis for system design.

Reconfigurable and modular simulation systems currently under development. One notable example of a modular trainer is the modular design trainer (MDT) which is reconfigurable to fit different training demands for operational flight training, cockpit procedures training, and the maintenance of tactical training proficiency (Rolston, 1992). MDT's have been developed for both fixed- and rotary-wing aircraft. Their high degree of reconfigurability should provide opportunities for research on the cost-fidelity tradeoffs required for effective training devices adaptable to different training environments.

Another example was developed by The Aircrew Training Research Division of Armstrong Laboratory, (AL/HRA) at Williams AFB, Arizona, which has been involved in the development of effective yet affordable squadron-level trainers since 1986. According to Boyle and Edwards (1992), AL/HRA's primary goal is to develop technology that both enhances training outcomes and lowers training costs. A modular, portable, F-16A/C trainer, the air intercept trainer (AIT), has been deployed at the squadron level, with 30 currently in use by Air Force Reserve and Air National Guard units. This training device exemplifies the development of simpler, dedicated trainers from more generalized and complex FMS's.

Among the laboratory's more recent developments is the multitask trainer, (MTT) a deployable simulator with a helmet-mounted display and fully functional cockpit. All of the computer systems needed to operate the MTT are self-contained. The MTT can be split apart to fit through a 36-inch doorway, allowing it to be installed in any classroom.

Training vs. Materiel Development.

It is important to state at the outset that STRATA's primary mission is training development, not materiel development. ARI is concerned with the impact of technology on training and human performance, not development and evaluation of the hardware itself. ARI is interested in hardware to the extent that its employment affects aircrew training, and raises important training, workload and other human performance issues. Nonetheless, STRATA could be used by materiel developers, in collaboration with ARI, to evaluate different technologies in the context of system performance. Finally, the training and performance impacts of current hardware provide feedback for future system design.

Projected Research

The summary to follow outlines the main issues and variables identified as critical to STRATA objectives. It should be made clear at this point that this is a research prospectus concerning possible investigations using STRATA. It is not possible to project, with certainty, precisely what every experiment will entail, or exactly what variables will be manipulated. In short, the outline presented below is to serve to impart to STRATA a programmatic structure. Obviously, research findings will modify future research plans. The fact that little research has been undertaken in areas identified in the prospectus makes it highly probable that frequent revisions will be necessary. The following sections are intended to discuss the direction and context of each research area.

Training Impact of Perception and Human Performance

Psychophysical Issues

An important set of questions to be addressed early in the STRATA research program will concern visual and motion psychophysical issues. For example, there is some evidence that apparent object distances are different in simulator and aircraft. The objective would be to measure quantitatively the systematic and variable errors that accompany estimates of speed and altitude. Current plans are to employ STRATA in a simulated daytime flight environment. One facet of this research would be target recognition and identification (e.g., ranges at which vehicles and their spatial orientations can be identified).

Quantification of these errors of estimate would provide valuable guidance for adjusting the size and configuration of simulated images in the tactical training environment to correspond to ranges as seen from the aircraft. As will be mentioned later, it could also aid the human factors researcher in the design of aircraft vision device imagery.

One limitation with most existing simulators is the lack of peripheral visual cues to motion. Another proposed area of research is to investigate the psychophysics of motion perception. Gibson (1979) demonstrated the importance of peripheral visual cues in the perception of motion. Gibson, Olum and Rosenblatt (1955), in their pioneering study, demonstrated there is a dynamic perspective to the perceptual array which tends to move away from the vanishing point in the center of the perceptual field as one looks forward toward the direction of motion. The perceptual array appears to move toward the vanishing point, if one looks opposite the direction of motion. These investigators showed that this ambient array of motion is critical for landing an aircraft.

ARI's planned research effort seeks to examine the perception of motion as an inherent, automatically-interpreted process. The strength of peripheral motion cues for all six degrees of motion could be investigated in the STRATA. In short, the project will examine the maximum degree of image change for a given amount of motion. The proposed research could provide new insights into the enhancement of these visual cues in simulators. Besides addressing these training and performance issues, it could suggest to materiel developers alternative displays for better representing these natural motion cues.

Two additional research possibilities should be mentioned briefly. First, STRATA has the potential of serving as a platform for studying the effects of visual degradation and differences in level of visual scene texturing on performance. This could provide opportunities for investigating night vision devices (NVD's) and the factors underlying the difficulties in detecting moving objects at night. Secondly, STRATA could be configured to investigate the psychophysics of motion (e.g., G-seat motion) on learning and performance.

Simulator Sickness

Cross and Gainer (1987) and Kennedy and Fowlkes (1990), upon review of the literature on simulator sickness, concluded that not enough is known about the effects of motion cues on simulator sickness. How motion cuing interacts with visual scene characteristics to promote or to retard simulator sickness and its effects is an open question.

Such investigations could serve as an impetus for future investigations of the value of G-seat motion cuing. It could also suggest future hypotheses concerning the possible interaction of motion cues and display characteristics.

STRATA lends itself well to the investigation of this phenomenon. Wright (in preparation) characterized simulator sickness as a variety of adverse symptoms, ranging from mild to relatively severe, which pilots attribute to the use of simulators. In general, these symptoms are reported to resemble motion sickness. The symptoms have sometimes been reported to linger for hours after the end of a simulator session.

Wright hypothesized that several interacting factors, most attributable to the differences between simulated and actual flight, may contribute to simulator sickness. As examples, he cited differences in the magnitude and timing of motion cues, including those washout cues added to cancel out sustained acceleration in operational simulators. In addition, he pointed out that the timing of visual cues differs substantially between aircraft and simulator. Many of the motion-related visual cues in the simulator are artifacts of the image generation system. Furthermore, differences exist in the timing of changes between motion and visual cues. This latter mismatch is believed to be a major factor in the induction of simulator sickness (see Kennedy, Berbaum, Allgood, Lane, Lilienthal and Baltzley, 1987; McCauley, 1984; Van Hoy, and Allgood, Lilienthal, Kennedy, and Hooper, 1987).

The modularity of STRATA and the presence of the G-seat provide an excellent opportunity to investigate the effects of vision and G-seat motion cuing, their timing, and the interaction of these variables on the onset and severity of simulator sickness.

In brief, STRATA is a testbed that can scientifically investigate a phenomenon that today is supported more by anecdotal than empirical evidence. The potential contribution of a scientific research program using STRATA is summed up quite well by Wright. He stated that none of the currently popular theories on the etiology of simulator sickness provide useful guidance for designing a simulator which minimizes the risk. This is the kind of guidance that STRATA could provide.

It is one thing to develop training strategies to minimize simulator sickness in currently-existing simulators. It is another to design simulators from the outset to minimize it.

Training Issues in Simulator Design

The following group of proposed research issues would address the cost and training effectiveness tradeoffs of various technical features of the simulator. The rationale for these research projects is to determine which features of the simulator are necessary for efficient training, and which ones are not.

Motion Cuing

The use of motion in simulators has been previously investigated for fixed-wing aircraft (Martin and Waag, 1978a, 1978b; Pohlmann and Reed, 1978; and Lintern, G., Wightman, D.C., and Westra, 1984). Results have generally failed to show any benefit from the use of maneuver motion, for acquisition and transfer of trai..ing. Research on rotary-wing applications is equivocal. Cross and Gainer (1987), in their review of simulation research, could only locate two research efforts which investigated the use and nonuse of motion cues in rotary-wing simulation (Feddersen, 1962; and Ricard, Parrish, Ashworth and Wells, 1981). The Ricard et al. (1981) research compared G-seat and platform motion systems to no motion. Experienced aviators attempted to maintain hover positions above a simulated ship. The investigators found that performance was best with platform motion, followed by the G-seat, and worst without any motion at all. Later research by Westra, Sheppard, Jones and Hettinger (1987) found dynamic G-seat cuing to be of no benefit for the same kind of task.

Cross and Gainer (1987) concluded that the reason for motion advantages in helicopter simulators was not clear. Several alternative explanations were explored, bearing upon inherent differences in helicopter vs. fixed-wing flight, and the artifactual differences caused by different visual scene and field of view (FOV) requirements. They concluded that maneuver motion probably is not advantageous for simulated helicopter flight where the FOV is wide. They added that this post hoc hypothesis could not be supported without future research involving both stable (cruise) and unstable modes (hover/gusts) of flight.

Vision Systems and Symbology

Comparison of different visual display systems. One of the most frequently discussed issues in simulation is the concept of visual fidelity (Allen, Hays and Buffardi, 1986; and Woodruff, Longridge, Irish and Jeffreys, 1979). ARI has used image generators of differing quality on its UH-1 based training research simulator (TRS). While no a priori comparisons between the imaging systems had been planned, and the training status of subjects differed between systems, it appeared that training effectiveness ratios were greater for the high than the low quality imaging systems (Wightman, Gainer, Dohme and Blackwell, 1991). This would seem to add credence to the proposition that increasing fidelity levels improve effectiveness.

STRATA can be configured to represent different types of visual displays. These configurations can reflect real-world trade offs due to acquisition and operating costs, site requirements, and the amount of pilot performance needed to maintain proficiency. One research project would compare the relative efficacy of STRATA's FOHMD with lower-cost alternatives, such as a rear-projection system. FOV comparisons could also be made within the FOHMD.

From previous FOV simulation research, (Westra et al., 1987) it would be reasonable to expect FOV restriction to be most detrimental to performance of lcw-level helicopter combat missions involving maneuvering and weapons delivery. Other potential manipulations include line rate, resolution, and eye-tracking. It is expected that for a large number of tasks, more economical displays would prove satisfactory. The FOHMD is expected to be effective across a broader range of piloting tasks, because of the better peripheral motion cues that it provides. The FOHMD would probably be mandatory for helicopter air-to-air combat training. A potential outcome of this research would be to provide input to materiel and training developers on essential cost-benefit trade offs for visual display systems.

Visual scene requirements for night vision (NV) device training. One critical area of research concerns the use of NV devices, such as forward looking infrared (FLIR) and image intensifier (I^2) systems. A representative research effort could employ a small number of high-time aviators, with experience in both of these systems, whose performance would be evaluated in STRATA. It could seek to examine the visual scene content and symbology requirements for these devices for the maintenance of combat readiness. Symbology could be addressed for navigation, target acquisition, and weapons delivery, for head-up displays, head-down displays, and helmet-mounted displays. The objective is to determine the relationship between I^2 and FLIR displays and the complexity required in the outside visual scene for effective training. Potential consequences of this project could be the development of training system requirements for design tradeoffs in the development of NV simulation devices. It should also produce valuable input to NV device developers as to the training and performance consequences of design alternatives.

Training requirements for Helmet-Mounted Display (HMD) technology. HMD technology is currently used in the AH-64 in the form of the integrated helmet display and sight system (IHADSS). The HMD was designed to reduce pilot workload and increase situational awareness in combat aircraft. STRATA could provide an excellent testbed for investigating the efficacy of HMD devices.

An example of a potential research question to be addressed is how the use of HMDs by AH-64 pilots affects performance during flight maneuvers. The planned experiment could also seek to determine the advantages and disadvantages of different HMD designs. The research might also address workload differences between pilots flying with night vision goggles (NVGs) alone and those flying with NVG-HMD systems. This research could also evaluate the effects of symbol sets and formats on aviator performance, assess the type and magnitude of individual differences in the use of symbols, and develop and evaluate methods to train aviators to use the symbology effectively.

The anticipated payoff for this research would be training requirements and attainable performance guidance for the development of advanced HMD's for future helicopters.

Training impact of FOV restriction. FOV has been shown to be a critical factor for simulated tasks where peripheral cue utilization is important, such as air refueling (Woodruff et al., 1979). For others, such as taking off and landing in the C-130 WST (Kellogg and Hubbard, 1989), its effects were not significant. Woodruff et al. (1979) found large main effects of scene complexity and FOV on the time required for subjects (all experienced pilots) to accomplish the performance criterion (three minutes in the air refueling envelope without involuntary disconnects). Kellogg and Hubbard varied the number of windows in the C-130 WST, and found no significant FOV effects on pilots' ability to make a short-field landing. They nevertheless concluded that the question of FOV remains controversial. Pilots were all experienced and the aircraft was initially aligned with the airfield. The lack of eye-tracking data makes it difficult to determine whether narrow FOV subjects compensated for the lack of peripheral cues by concentrating on additional central cues.

A series of experiments by Westra et al. (1987) showed large effects due to FOV for a simulated helicopter shipboard landing task. Lack of peripheral cues and the use of low-resolution visual displays made this task extremely difficult for experienced Navy helicopter pilots. This suggests that FOV may be critical for typical helicopter operations, such as landing from a hover.

One problem with NV devices is their restriction of the pilot's FOV. This proposed research could have as its objectives the determination of the most effective procedure for an aviator to use the limited FOV afforded by vision systems, and the development of training strategies for the use of these devices. The research could assess current pilot strategies employed with night vision devices and eye scan behavior in the simulator. Pilots could be trained in optimized eye scanning techniques, and their flight performance compared to a control group that has not been so trained. This research could result in the development of optimal simulator and aircraft instructional strategies for the employment of devices that restrict pilot FOV.

Texturing. Research using fixed-wing simulators has manipulated the detail of texturing. In general, research has shown that more complex visual displays provide pilots with important altitude-maintenance cues (Kraft, Anderson and Elworth, 1982). Kraft et al. found that pilot performance and training time in the simulator were significantly better when the visual scene was complex than when it was simple. Likewise, Kellogg and Hubbard (1989), found that a textured visual scene in the C-130 weapon systems trainer (WST) significantly aided pilots in performance of the landing task. These two pieces of research have little relevance to the modeling texturing technology and the levels of complexity available in STRATA.

A fundamental issue that should be addressed early on in the STRATA research program is the level of simulator scene detail required for experienced pilots to maintain their flying skills. The objective of this research could be to emulate the most effective level of scene detail, in terms of training outcome and cost trade offs, from various image generating systems, for use in a helicopter simulator.

Experienced AH-64 aviators could fly mission scenarios representing those typically flown in attack missions with this aircraft. Performance measures could be assessed during each segment of the simulated mission. The results should assist in providing guidance for the acquisition of the most effective visual image generators for helicopter simulators, in the context of specified training objectives.

A follow-on experiment could target those particular features of the visual display that are necessary for desired performance outcomes. It could address the actual content of the visual scene along various dimensions and would build upon U.S. Air Force research on multidimensional scaling (Kleiss, 1990) of real-world visual scenes viewed from various altitudes. The content of visual scenes (for example, the degree of realism of various trees; texturing of objects and terrain) would be examined.

Pilots would fly a set of visual flight paths differing in level of complexity along dimensions such as these. It is anticipated that pilot performance may be somewhat poorer for scenes containing less task-relevant information. It is also possible that those complex scenes with a large of amount of task-irrelevant visual information may not facilitate pilot performance, or may even detract from it. Results could provide training system developers with guidance as to which aspects of the visual scene should be modeled with greater complexity, and which do not require it.

Another feature to be considered would be the control response timing lag in the simulator visual scene, in excess of those encountered in actual flight. The amount of timing lag could be varied, and its effects on performance assessed. This would provide an indication on the amount of lag that can be tolerated in a training device, versus the level at which the effects of lag become detrimental to effective training.

Tactical and Operational Training Issues

Training Aids and Strategies

Development of performance measurement systems. For many operational training simulators, student performance is assessed via subjective ratings by instructor pilots. This approach to performance measurement persists, even though the capability to capture and store objective performance data automatically has existed for over a decade. Thus the development of the automated performance measurement system (PMS) has lagged behind the rapid evolution of simulators (see Kelley, 1988; and Vreuls and Obermayer, 1985, for a review of PMS research).

Interest in PMS research is not a recent development. Hennessy, Hockenberger, Barnebey, and Vreuls (1979) developed an error-based automated performance measurement and grading system for the Army's UH-1 flight simulator. In an earlier effort, Vreuls and Obermayer (1973) explored the development of quantitative, machine-based performance measures for the Navy's Jaycopter captive rotary-wing training device. It would seem then, that the lag in the development of PMS systems is more one of priority than technology.

Data Recording and Analysis (DRA) system. STRATA's automated data recording and analysis (DRA) system could provide an excellent opportunity to develop methodologies for measuring complex performances. This in turn should lead to significant advances in the program evaluation methodologies used to assess performance of alternative systems. A series of experiments could compare alternative weapon and/or training systems. The objective would be to develop a quantitative methodology for evaluating the performance of these alternative systems. Systems could be either currently-fielded, developmental, or notional.

Figure 4 shows the role of the DRA in the context of a major operational problem: the need for objective measures of aviator performance as well as to determine which of these measures discriminates effective from ineffective performance. The DRA is shown as having three major functions: the ability to record performance data, the specification of parameters to be captured (e.g., airspeed, altitude, heading, various control movements), and the specification of time and/or event "triggers" to begin and end data recording. The recording, playback and control of data recording can be accomplished from the experimenter operator station (EOS). The interactive tactical environment management system (ITEMS) can be used to determine performance parameters in the tactical environment, such as the vulnerability of the AH-64 to simulated threats, the effects of wind on trajectory of weapons, and weapons scoring. Together these STRATA subsystems can be used to conduct research on objective performance measures, and to determine which of these measures have the most validity.

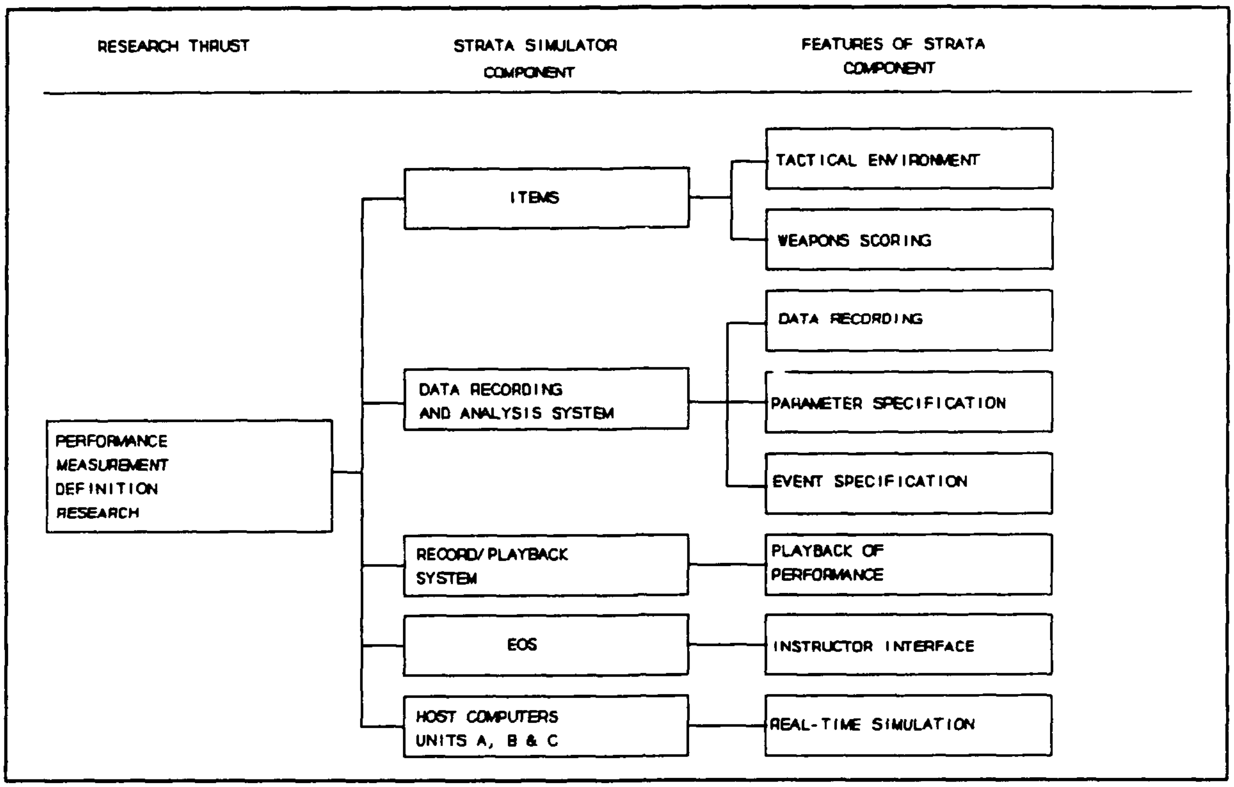

Figure 4. Performance measurement research components and features of STRATA.

Modeling of systems and task analysis for crew roles could first be carried out for each system under consideration. Next, dependent variables may be defined within STRATA's automated DRA. A set of flying tasks such as autorotation, landing and hovering could then be performed, and alternative measures of performance compared.

The intelligent flight trainer (IFT). An ARIARDA research initiative is the development of simulation and artificial intelligence (AI) technologies to create an IFT. Currently, the IFT is hosted by a low cost UH-1 primary training simulator. Research has demonstrated that Army student pilots can rapidly learn basic hovering skills in the low cost IFT without the requirement for an instructor pilot (Dohme, 1991). Fiscal Year 1994-95 plans call for adapting the IFT technology to the STRATA device to demonstrate the generality and portability of the IFT concept. Flight maneuvers will be selected for training from a mission area not routinely trained to AH-64 aircrews (e.g., air-to-air gunnery maneuvers). The IFT will train AH-64 pilots in these maneuvers. Next, the transfer of training of these flight skills will be assessed.

Aerial gunnery training research. ARI has recently conducted research on the effectiveness of the AH-64 combat mission simulator (CMS) for maintaining gunnery skills (Hamilton, 1991). The results of the research were inconclusive. Experienced aviators allowed to practice their gunnery skills in the CMS, in addition to their normal flight routines, did not outperform those who had been restricted from doing so. Hamilton speculated that this lack of differentiation of CMS and control groups was due to the six month interval between training and live-fire practice. Sufficient time had not passed for the live-fire skills to deteriorate. The question of the optimal time interval and of the best training devices and strategies for maintenance of these skills remains open. STRATA has the precision to accurately measure degrees of skill decay over time, and the effects of training in skill restoration.

The objectives of this proposed research are to determine if improved simulation of weapons systems enhances the transfer of training from STRATA to live-fire gunnery in the aircraft and enhances the transfer of training in institutional courses. During Phase One, training effectiveness could be assessed for operational crews by comparing the performance of crews trained in the AH64CMS with those trained in STRATA. In Phase Two, another experiment could compare gunnery performance of two groups of aviators from the AH-64 Aircrew Qualification Course. Half would have been trained in the CMS, the other half in STRATA. Data from these experiments could be used to evaluate the possible advantages of alternative weapons simulations for initial gunnery training. The data may also indicate the relative contribution of procedural and the dynamic aspects of weapons simulation on training effectiveness.

Helicopter air-to-air combat. Two examples of planned research are concerned with a relatively new operational scenario for helicopters, air combat maneuvering (ACM), especially under nap-of-the-earth (NOE) conditions. This could draw heavily upon lessons learned from previous research on fixed-wing ACM, especially in the context of automated performance measurement and other means of evaluating training outcomes (Kelley, 1988).

The first project could explore the techniques required for ACM training. In order to accomplish this goal, two objectives must be met. First, visual cuing requirements and optimal presentation order for ACM techniques (e.g., banking turns, climbing flight, scanning and coordination within and between crews) would be defined. Second, instructional strategies and techniques for efficient and effective ACM training could be defined. Task ordering and cues used for instruction and performance evaluation would be compared using ACM-naive aviators as subjects. A small number of experienced ACM-qualified aviators may also be required. The payoff of this research would be guidance for the development of an ACM instructor pilot training curriculum.

Another question that would be addressed concerns the utilization of weapons systems currently under development in a helicopter air-to-air environment. The proposed characteristics of each new weapons system could be modeled in STRATA weapons suite. ITEMS represents the latest state of the art in the portrayal of forces and elements in a dynamic battlefield simulation. The system would then be employed in ACM scenarios. Instructional programs would then be outlined and verified, emphasizing novel procedures and presenting the rationales underlying their use. The research design may require a small number of ACM-qualified pilots, and, to assess acquisition of ACM skills, ACM-naive pilots. One possible outcome of the research would be the identification of techniques for optimal utilization of weapons systems. Another would be the development of instructional strategies for training aviators in the operation of these systems.

Training Unmanned Aerial Vehicle (UAV) operators in a simulator. Potential workload and training problems were identified by ARI during operational testing of a recent prototype UAV system, the Army's Aquila (Stewart, Smootz and Nicholson, 1989). STRATA provides the technology to simulate the working environment of the UAV operators. This capability could provide an opportunity to resolve the training and workload problems systematically.

The objectives of this research would be to (a) develop a UAV simulator-based training program, (b) assess the scene content necessary for task performance, and (c) determine the degree of transfer of training from simulator to UAV operator station. The first phase of the project could draw upon the extensive task and workload analyses that have been performed on the three UAV crew positions: the air vehicle, mission payload, and launch and recovery operators (see Byers, Bittner, Hill, Zaklad and Christ, 1988). Various programs of instruction and operating manuals would be reviewed to determine which tasks are appropriate for simulator training. A sample of operators could be interviewed for the same purpose.

The potential product of this research would be guidance and standards for the Army, Navy, and Air Force on the development and implementation of simulators currently planned for future UAV training programs.

Planning and Decision-Making

Accident scenario training. The ARI safety research program has explored new approaches to the diagnosis and analysis of Army aviation accidents (Friedman, Leedom and Howell, 1991). These investigators developed a descriptive synopsis approach which could be used by accident investigators to pinpoint critical incidents and tasks that precipitated accidents. The synopsis was shown to elicit high consensus among independent raters as to the tasks that caused accidents, and the human skills and attitudes that could preclude similar accidents in the future. A logical next step would be to recreate Army aviation accident scenarios in STRATA. Investigators could identify specific tasks and errors that may lead to accidents, and develop instructional strategies aimed at minimizing the recurrence of accidents.

Two research projects have been proposed to address STRATA's capabilities of simulating actual aircraft accidents, and its potential as a training, diagnostic, and preventive tool integral to future training programs.

The initial research would examine configuring STRATA to replicate Army helicopter accidents. The procedures could be developed for entering data into simulators about environmental conditions, personnel, and materiel factors involved in each accident. STRATA could simulate conditions present at the time of an accident. This could determine the most plausible cause(s) for each crew error, and identify remediation methods. The research could provide the Army with a means of accurately evaluating Army aviation accidents attributed to human error. It might also aid in the development of improved training strategies on the basis of lessons learned.

The emphasis for the second research effort could be on the examination of training issues related to aviation safety. Investigators could develop accident training scenarios, and assess their cost and training effectiveness. The research could consist of three sequential tasks: (a) the selection of a small sample of accident types to be investigated, (b) the development of training scenarios for the target accidents, and (c) contribute data relevant to an evaluation of training and cost effectiveness. STRATA may be used for the latter two tasks. This research project would identify those specific search, perceptual judgment, and information processing skills required for safe crew coordination and functioning in hazardous situations.

<u>Tactical decision-making by Army rotary-wing aviators</u>. When aviators must make time-limited judgments, they are often forced to rely on their own cognitive strategies. Cognitive models for decision-making can be assessed at the level of the aircrew as well as the individual (Thordsen, Klein and Wolf, 1992). ARI investigators would like to uncover the decision-based rules used by aviators in situations requiring rapid decisions. Secondly, they would be interested in learning how these implicit rules can be altered to avoid potential systematic errors that may arise from them. This kind of research can provide an objective database for input to advanced systems cognitive decision aids, such as is planned for the rotorcraft pilots' associate (RPA).

Researchers could observe and describe the decision-making strategies used by Army aviators in a range of simulated combat situations. Next, the more effective strategies could be defined by the Army and validated against the same simulator scenarios. By comparing observed and optimal strategies, requirements for decision support or decision-making training could be defined. After development of the necessary training and support aids, the effectiveness of alternative training methods for decision-making could be evaluated by comparing their efficiency and effectiveness. This project should demonstrate the often less than logical manner in which persons reason about complex uncertainties and conflicting objectives frequently encountered on the battlefield.

Premission and tactical decision aids. Cox and Ruffner (1980) defined premission planning as that group of tasks which should be performed from the time the aviator receives the mission operational order up to and including the time of aircraft runup. They regarded premission planning as an essential precursor to any mission. However, they considered it most critical to missions involving terrain flight navigation. On this type of mission, crewmembers must rely on paper maps, and the chances of geographical disorientation are high. These authors cited several research projects that implicated faulty premission planning as the principal factor in terrain flight mission failures.

The rapid development of automated mission planning and rehearsal devices (MPRD) promises to enhance the effectiveness of the premission planning and rehearsal (or preview) process. MPRDs are now available which are cost-effective, portable, and MS-DOS compatible. Most employ digitized maps, while some use SPOT satellite imagery or have the capacity to overlay digitized terrain with various kinds of photo imagery. Route updating could be accomplished quickly, without the use of cumbersome maps or overlays. Routine calculations could be automated, minimizing probability of error.

The objectives of the proposed training-related research could be to (a) determine just how effective automated MPRDs are when compared to the traditional manual process, (b) assess the human factors aspects of MPRDs, in terms of user compatibility, (c) examine alternative displays and data presentations (e.g. digitized vs. SPOT), and (d) explore alternative uses of the devices along with different combinations of training media.

A related area which could provide fertile ground for research using STRATA is the RPA. RPA is a major applied technology demonstration of the U.S. Army Aviation and Troop Command (USAATCOM). It will be an automated decision-making "copilot" consisting of map displays, route listings, synthetic voice and audio message alert systems, and other interactive subsystems intended to reduce cognitive workload and facilitate tactical decision-making.

RPA should assist the pilot in updating threat locations during a mission, and in optimal route selection so that these threats are evaded with no degradation in mission performance. The training and workload implications surrounding the introduction of the RPA are considerable. Whether RPA will allow a single pilot to perform a mission profile that normally requires two pilots is an example of a crucial training and performance question that STRATA could address.

The positive outcomes from this research could be the improvement of mission performance through more effective planning before, and better decision-making during the mission. Finally, alternative training strategies for teaching the skills required to plan and execute a mission could be developed.

<u>Subjective Workload Measures and their Relationship to Training</u>

<u>Validation of AH-64 workload prediction model</u>. A task analysis workload (TAWL) prediction methodology has recently been developed at ARI for the AH-64 (Hamilton and Bierbaum, 1992). TAWL has been applied to other Army helicopters as well. However, none of the specific models produced by the TAWL methodology have been validated. STRATA, with its automated DRA, could provide an excellent opportunity for determining the degree of fit between TAWL workload predictions and actual aviator performance in the simulator.

Investigators would first need to select criteria against which TAWL predictions would be validated. The research could consist of two phases. First, subjective, physiological, and objective PMS measures would be collected for mission segment. Mission realism could be sacrificed for the experimental control needed to collect accurate TAWL measures. These independent measures of workload could be compared to predictions generated by the TAWL workload prediction model for each segment. Next, the same independent measures of workload could be collected during full mission simulation.

If validated, the AH-64 workload prediction methodology should provide a baseline for estimating the training and workload impact when new helicopter systems are introduced, or when other systems are retrofitted to current helicopters. It could also serve as an indicator of those phases of a mission where pilots may become overloaded and their performance degraded. Training strategies could be developed to cope with the potential of excessive workload demands for specific aviator tasks. Furthermore, tasks with potentially high contributions to workload can be identified by materiel developers as candidates for equipment automation.

Validation of the Micro Saint crew level error model. ARI recently developed a crew level error model for two versions of the UH-60 Blackhawk helicopter (Griffith and Stewart, 1991). This model could be modified to represent the AH-64 Apache. The Micro Saint model uses TAWL to generate workload values continuously during a model run. These values in turn drive complex algorithms that predict various crew errors (missed checkpoints, failure to acquire a checkpoint visually, deviation from ground track course, mission time outs, and probability of rotor blade tree strikes).

The mission scenario represented in the Micro Saint model can be adapted to STRATA. Crews varying in mission experience crew familiarity could fly simulated missions in STRATA. The DRA system would capture terrain flight navigation and obstacle clearance errors similar to those used as performance measures in the Micro Saint model.

This research could provide the Army with a simulator-validated model of AH-64 crew performance. It would also provide a training tool for estimating outcomes such as the probability of mission success or failure, for crews varying in mission experience and familiarity.

Training Impact of Tactical Display and Sensor Technology

LONGBOW is an advanced radar system that will soon be retrofitted to some AH-64A's. An important question is how the tasks required to operate LONGBOW will impact pilot performance in the aircraft and training requirements.

Targeting priority integration for LONGBOW. One example of a proposed research project could seek to determine how much training time is required to minimize crew performance time and workload and to improve accuracy in target identification and confirmation for aircrews using LONGBOW. A second objective could be the development of training options for enhancing crew performance in target prioritization in battlefield situations.

The expected results of this effort would be the indication of possible improvements in target identification times via training versus control-display alternatives. This may be expected to improve survival and reduce the risk of fratricide.

Display content requirements for Airborne Target Handover (ATHS) systems. Combat readiness training must keep up with the ATHS and related technologies. Research could determine the effective symbologies and training for use with the head-down display (HDD), head-up display (HUD) and the HMD in the context of the ATHS combat readiness training. The research would quantify the control-display and scene content necessary for effective training in using ATHS in air-to-ground and air-to-air combat operations. This research should also contribute to the development of specifications and design standards for ATHS for future helicopters such as the RAH-66 Comanche.

Display and scene content requirements for sensor fusion displays. The pilots of combat aircraft will in the near future be operating with a variety of electronic sensor devices. STRATA could serve as a research platform for determining the display content of multiple sensors and the visual scenes represented. Sensor fusion displays will present the input from a variety of sensors (e.g. passive and active radar, electro-optical, Infrared) to HUDs, HMDs, and head-down displays on the AH-64 and other aircraft. The amount of data that can be displayed at any one time is limited in part by the ability of the pilot to process this information while flying the aircraft. The research proposed could examine various trade offs between sensor data input to the displays and the representation of the visual scene outside the cockpit. This research could provide the Army with guidelines for the development of training programs using sensor fusion displays.

Display and visual scene content requirements for tactical information display systems. The objectives of this proposed research could be the determination of symbology and display characteristics required for effective helicopter crew training, and the training methodologies needed for combat readiness. Both the joint tactical information distribution system (JTIDS) and joint surveillance target acquisition and retrieval system (JSTARS) proved themselves effective in Desert Storm. Specific symbologies, display requirements and training strategies remain to be developed for helicopter combat operations. A product of this research effort could be specifications for display and visual scene content, for use in developing helicopter training programs related to JTIDS and JSTARS.

Summary and Conclusions

The research issues that have been presented were driven by an a priori assessment of the development of training device and aviation display technologies. Many research questions remain unresolved, especially for those aspects of rotary-wing flight that are unique. As the STRATA program matures, it is certain that many of these plans will be modified. Also, new research plans will be generated as Army aviation training requirements and priorities change. For example, if technological breakthroughs result in the availability of relatively inexpensive, yet high resolution visual display systems, then exploration of training outcomes employing degraded resolution displays could become moot.

Likewise, major changes in mission requirements and in doctrine could occur over the next few years. This would probably impact the agenda of events for STRATA.

Nonetheless, STRATA will certainly prove a useful research tool for resolving those research issues which directly affect the training and cost effectiveness of Army flight simulators. The foregoing statement is even more pertinent to rotary wing simulators and training devices. Little research of any kind has been done on the employment of these training systems. The need for developing effective training systems, of which the simulator is an integral part, should remain a priority throughout the 1990s, regardless of technological or doctrinal changes.

At the outset of this prospectus, it was noted that the research database in the area of flight simulation, especially helicopter simulation, is deficient. This means that there is virtually no precedent for developing and evolving an integrated network of theoretical constructs. What is needed, and what this prospectus seeks to provide, is a general road map and operating concept for STRATA. By analogy, the present map may be crude in places, but this is true for the early stages of any campaign of discovery and exploration. As more of the theoretical and empirical world became known, the maps become more detailed and accurate, and navigation becomes routine. Most of the research has been directed as specific applications and operational issues, not the development of theoretical constructs. STRATA, as a dedicated research tool, should provide a starting point for theory-building in aviation psychology.

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